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UNITED STATES PATENT APPLICATION

FOR

METHOD AND SYSTEM FOR USING AN AUDIO TRANSDUCER AS BOTH AN INPUT AND OUTPUT DEVICE IN FULL DUPLEX OPERATION

Inventors:

Lawrence A. Leske
David L. Medin

Sawyer Law Group LLP
2465 E. Bayshore Road
Suite 406
Palo Alto, CA 94303

METHOD AND SYSTEM FOR USING AN AUDIO TRANSDUCER AS BOTH AN INPUT AND OUTPUT DEVICE IN FULL DUPLEX OPERATION

FIELD OF THE INVENTION

The present invention relates generally to audio transducers and more particularly to an audio transducer as both an input and an output device in full duplex operations.

BACKGROUND OF THE INVENTION

Full duplex speakerphone telephone sets and intercoms are common devices. However, they require the use of two audio transducers, one as the speaker and the other as the microphone, for full duplex operation. It is also known that speakers can be utilized as both a speaker and a microphone in a speakerphone system. When speakers are used, however, they are utilized as microphones in a half duplex mode. In so doing, one communicator has to wait for the other to stop talking or there is significant distortion.

What is desired is to provide a speakerphone system where only one transducer is utilized but allows for full duplex operation. The system must be easy to implement, adaptable and compatible with existing speakers utilized in a speakerphone system. The system should not add significant cost to the

speakerphone system. The present invention addresses such a need.

SUMMARY OF THE INVENTION

The present invention provides a method and system for using an audio transducer as both an input device and an output device. The method and system include digitally modulating a primary input signal for driving the transducer as an output device, sampling an output signal generated from the transducer during off times of the modulated signal, and determining an input signal from the sampled output signal.

In addition to the cost advantage of replacing the microphone with the existent loudspeaker (transducer), other benefits gained include: (1) the elimination of the acoustic feedback path from speaker to microphone, which would normally require additional circuitry to suppress the "howling" which could occur; (2) increased quality of audio as a result of the use of the speaker as the microphone instead of a usually more distorting separate microphone; (3) increased audio quality due to the better signal provided to echo canceling circuit from the speaker without having the significant echo directly from the speaker to microphone acoustic feedback path.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram illustrating a bi-directional audio frequency circuit for use in a speakerphone or intercom set in a preferred embodiment of the present invention.

Figure 2 is a flow chart illustrating the process for using the audio transducer as both an input and output device in full duplex operation according to a preferred embodiment of the present invention.

Figure 3 is a diagram illustrating detail of the sampling time in which the audio transducer is used as a microphone.

Figure 4 is a block diagram illustrating a second preferred embodiment of the bi-directional audio controller.

DETAILED DESCRIPTION

The present invention relates generally to audio transducers, and more particularly to an audio transducer as both an input and an output device in full duplex operations. The following description is presented to enable one of ordinary skill in the art to make and use the invention and is provided in the context of a patent application and its requirements. Various modifications to the preferred

embodiment and the generic principles and features described herein will be readily apparent to those skilled in the art. Thus, the present invention is not intended to be limited to the embodiment shown but is to be accorded the widest scope consistent with the principles and features described herein.

The present invention provides a full-duplex hands-free audio frequency circuit that uses a single transducer as both the microphone and loudspeaker for an intercom or telephone set, such as a voice over IP (VoIP) system. The audio frequency circuit simultaneously utilizes the single speaker both as an audio output device and as an input device, replacing the customary microphone. The audio frequency circuit is useful with any output power controller similar to a digital switching Class D or Class G amplifier that utilizes any form of digital pulse modulation.

Figure 1 is a block diagram illustrating a bi-directional audio frequency circuit for use in a speakerphone or intercom set in a preferred embodiment of the present invention. The bi-directional audio frequency circuit 100 includes a telephone system interface 102, a digital pulse modulating amplifier 103, a modulating power switch 117, a transducer 106, and a microphone generation circuit 101 that allows the transducer 106 to operate as a microphone, while it is operating as a speaker in full duplex mode.

In operation, the telephone system interface 102 transmits a primary input signal 120 to the digital pulse modulating amplifier 103, such as a Class G, Class D, or similar amplifier, which produces a digitally modulated signal 122. As is well known in the art, a digitally modulated signal 122 continually transitions between two states: active and inverted. When the modulated signal 122 is active, the modulating power switch 117 switches on and drives the audio transducer 106 as a speaker (output device). When the modulated signal 122 is inverted, the power switch 117 switches off.

According to the present invention, during the power switch 117 off-times, the microphone generation circuit 101 uses the audio transducer 106 as an input device, as explained further below. In a preferred embodiment, the microphone generation circuit 101 accomplishes this function using an amplifier 108, sample control logic 107, A/D converter 109, audio filter 110, signal normalizer 105, echo canceling filter 104, and amplifier 113.

Figure 2 is a flow chart illustrating the process for using the audio transducer as both an input and output device in full duplex operation according to a preferred embodiment of the present invention. The process begins in step 200 by detecting when the modulated signal 122 is inverted, and consequently also detects when the

power switch 117 is not driving the audio transducer 106 (i.e., the off-times). In response, EMF output voltage 124 (or current) from the audio transducer 106 is sampled in step 202.

Figure 3 is a diagram illustrating detail of the sampling time 300 in which the audio transducer is used as a microphone. During power switch 117 on-times 302 and 305 of the digital modulated signal 122, the audio transducer 106 is used as an output speaker. Referring to both Figures 1 and 3, during power switch 117 off-times 303 and 304, the sample control logic 107 detects the inverted digitally modulated signal 122 and activates the A/D converter 109. The A/D converter 109 then samples the speaker back EMF output voltage 124 and/or current in order to detect an input audio signal 126 after the EMF output voltage 124 is amplified by amplifier 108.

The output voltage 124 input to the A/D converter 109 is a result of the motion of the transducer 106, both from sound being generated due to the drive signal, and from sound impinging from local audio sources, especially the voice of the local user. Referring again to Figure 2, since the sampled input audio signal 126 will generally operate as a sample rate higher than the final audio sample rate need it, an audio filter 110 may be used to down-convert the input audio signal 126 and to minimize high frequency induced noise from the speaker drive circuitry in

step 204.

When the modulated power switch 117 is active, the current injected into the transducer 106 by switch 117 generates a magnetic field in the transducer's coil, which acts with accelerative forces on the transducer 106. When the modulated power switch 117 is off, the transducer 106 continues to move due to inertia. When the transducer 106 is active as a speaker output device, the largest component of the signal from the transducer 106 is a result of the output from the modulating power switch 117, even when the digitally modulated signal 122 is inverted and the power switch 117 is off. As a result, whenever the transducer 106 is used as an input device (microphone), the effects of the modulating output signal must be removed from the sampled input audio signal 126 to prevent echoes. Failure to do this could result in highly disturbing echoes or "howling" from this feedback loop.

Referring again to Figure 2, the present invention significantly reduces these effects in step 206 by using the signal normalizer 105 to normalize the primary input signal 120, and subtracting the normalized primary input signal 120 from the filtered input audio signal 126 at circuit 111 to create a clean version of the "microphone" input signal. This technique may also be used to minimize or eliminate locally generated sound, such as music or PC videogame sound effects, which would normally be played through the speaker. Thus, even though the user may clearly

hear music playing, a remote communicator may not hear the music at all, or depending on the order of precision of the audio filter 110, may only hear the sounds at a very low nonintruding-level.

In order to additionally prevent room echoes from disturbing the conversation, an step 208 may optionally be performed in which the echo canceling filter 104 is used to cancel echoes from the primary input signal 120 and then the pseudo echo signal is subtracted from the normalized and filtered input signal 126 by circuit 112. Signals at 127 and 128 are training signals, used to adjust the filter coefficients for optimal echo cancellation. Echo canceling filters are well known in the art, see for example, U.S. Patent No. 3,500,000. The resulting signal is then amplified as necessary by amplifier 113 for output to telephone system interface 102 in step 210.

Figure 4 is a block diagram illustrating a second preferred embodiment of the bi-directional audio controller, where like components of Figure 1 have like reference numerals. The second embodiment is identical to the first embodiment, but includes an audio/PC interface402. In this circuit 400 any local audio source from the audio/PC interface 402 may be added to, or mixed with the primary input signal 120 at circuit 404. The mixed primary input signal 120 is then utilized by the digital modulator 103 for speaker output, as well as by the signal normalizer 105,

and the echo canceller 104 to enable the removal of these unwanted signals from the microphone input signal 126.

Thus, this embodiment of the present invention provides the user with the ability to listen to a secondary input signal, such as PC audio or another caller, and have the echo canceller 104 subtract the secondary input signal from the microphone input, which effectively mutes the secondary input signal from the caller. The primary advantages are:

1) The ability for the user to listen to background music without the caller hearing the
music;

2) In a conference call, two or more outside parties can be joined electronically (and digitally) as apposed to acoustically, which enables a) a cleaner connection and b) the ability to adjust volume of each party independently for each party; and

3) During a conference call, the outside parties can be selectively and individually muted by the user.

A method and system for using an audio transducer as both an input and output device in full duplex operation has been disclosed. Although the present invention has been described in accordance with the embodiments shown, one of

ordinary skill in the art will readily recognize that there could be variations to the embodiments and those variations would be within the spirit and scope of the present invention. Accordingly, many modifications may be made by one of ordinary skill in the art without departing from the spirit and scope of the appended claims.